AN2813
Application note

TDE1708DFT in IO-Link applications

1 Introduction

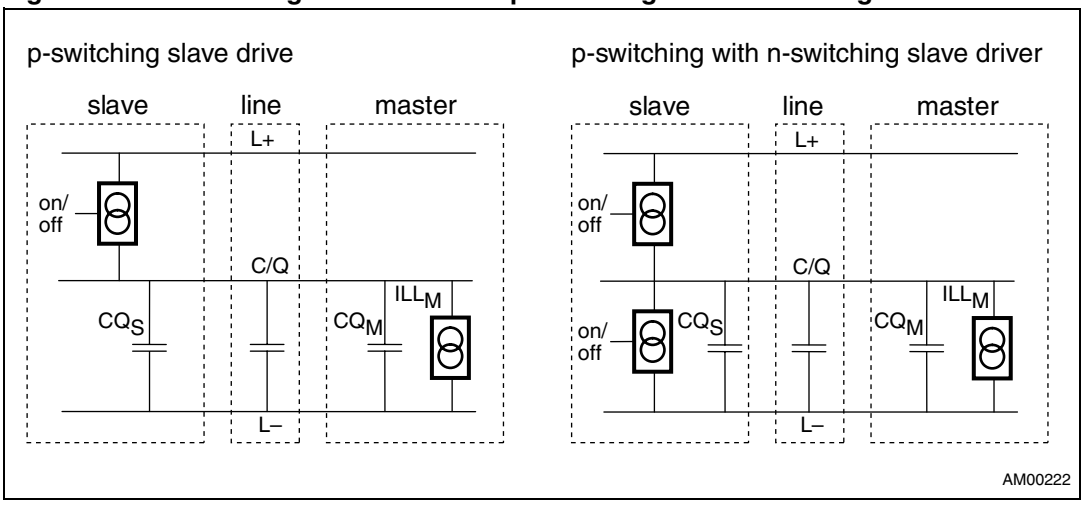
This application note investigates the possibility of using a TDE1708DFT switch for the physical layer transmitter realization of 3-wire IO-Link sensors.

The TDE1708DFT is an integrated power switch especially dedicated to proximity detectors. It can deliver up to 250 mA, enables high-side and low-side configurations and includes a number of protections.

According to the IO-Link Communication Specification (see *Section 8: References -3.* and for the TDE1708DFT features - see *Section 8: References - 1.*) two basic slave transmitter configurations were tested (see *Figure 1*):

- p-switching (high-side) driver
- p-switching driver with an additional n-switching (low-side) driver (push-pull operation)

Figure 1. P-switching slave drive and p-switching with n-switching slave drive



In the following test arrangements the input load current (ILL_M) is fixed to 10 mA which represents the average master current sink value specified for a 3-wire system. The master (CQ_M), slave (CQ_L), and line capacitances are set together at 4.7 nF, corresponding to the maximum parasitic capacitance of the system.

Contents

1 **Introduction** 1

2 **TDE1708DFT in high-side configuration** 5

2.1 High-side configuration 5

2.2 High-side configuration with a capacitive load 7

3 **TDE1708DFT in low-side configuration** 9

3.1 Low-side configuration 9

3.2 Low-side configuration with a capacitive load 11

4 **Push-pull configuration with TDE1708DFT** 13

5 **Performance characteristics** 18

5.1 Dynamic information 18

5.2 Temperature characteristics 18

6 **Alternative driving** 19

6.1 Temperature characteristics 22

7 **Conclusion** 24

8 **References** 24

9 **Revision history** 24

List of tables

Table 1. Push-pull configuration dynamic information (V_{CC} = 24 V; T_J = 25 °C; C_L = 4.7 nF) 15
Table 2. Dynamic information (V_{CC} = 24 V; T_J = 25 °C; I_L = 10 mA) 18
Table 3. Document revision history 24

List of figures

Figure 1. P-switching slave drive and p-switching with n-switching slave drive . . . 1
Figure 2. High-side switch test configuration schematic . . . 5
Figure 3. High-side switch configuration turn-on behavior . . . 6
Figure 4. High-side switch configuration turn-off behavior . . . 6
Figure 5. High-side switch test configuration schematic with a capacitive load . . . 7
Figure 6. High-side switch configuration with a capacitive load turn-on behavior . . . 8
Figure 7. High-side switch configuration with a capacitive load turn-off behavior . . . 8
Figure 8. Low-side switch test configuration schematic . . . 9
Figure 9. Low-side switch configuration turn-on behavior . . . 10
Figure 10. Low-side switch configuration turn-off behavior . . . 10
Figure 11. Low-side switch test configuration schematic with a capacitive load . . . 11
Figure 12. Low-side switch configuration with a capacitive load turn-on behavior . . . 12
Figure 13. Low-side switch configuration with capacitive load turn-off behavior . . . 12
Figure 14. Push-pull test configuration schematic . . . 14
Figure 15. Push-pull configuration with capacitive load rising edge . . . 15
Figure 16. Push-pull configuration with capacitive load falling edge . . . 16
Figure 17. Software timing example . . . 17
Figure 18. Propagation turn-on time vs. temperature . . . 18
Figure 19. Propagation turn-off time vs. temperature . . . 18
Figure 20. Alternative driving schematics . . . 20
Figure 21. Alternative driving timings . . . 21
Figure 22. Delay propagation turn-on time vs. temperature (H. S. configuration) . . . 22
Figure 23. Delay propagation turn-on time vs. temperature (L. S. configuration) . . . 22
Figure 24. Propagation turn-off time vs. temperature (H. S. configuration) . . . 23
Figure 25. Propagation turn-off time vs. temperature (L. S. configuration) . . . 23

2 TDE1708DFT in high-side configuration

2.1 High-side configuration

Figure 2. High-side switch test configuration schematic

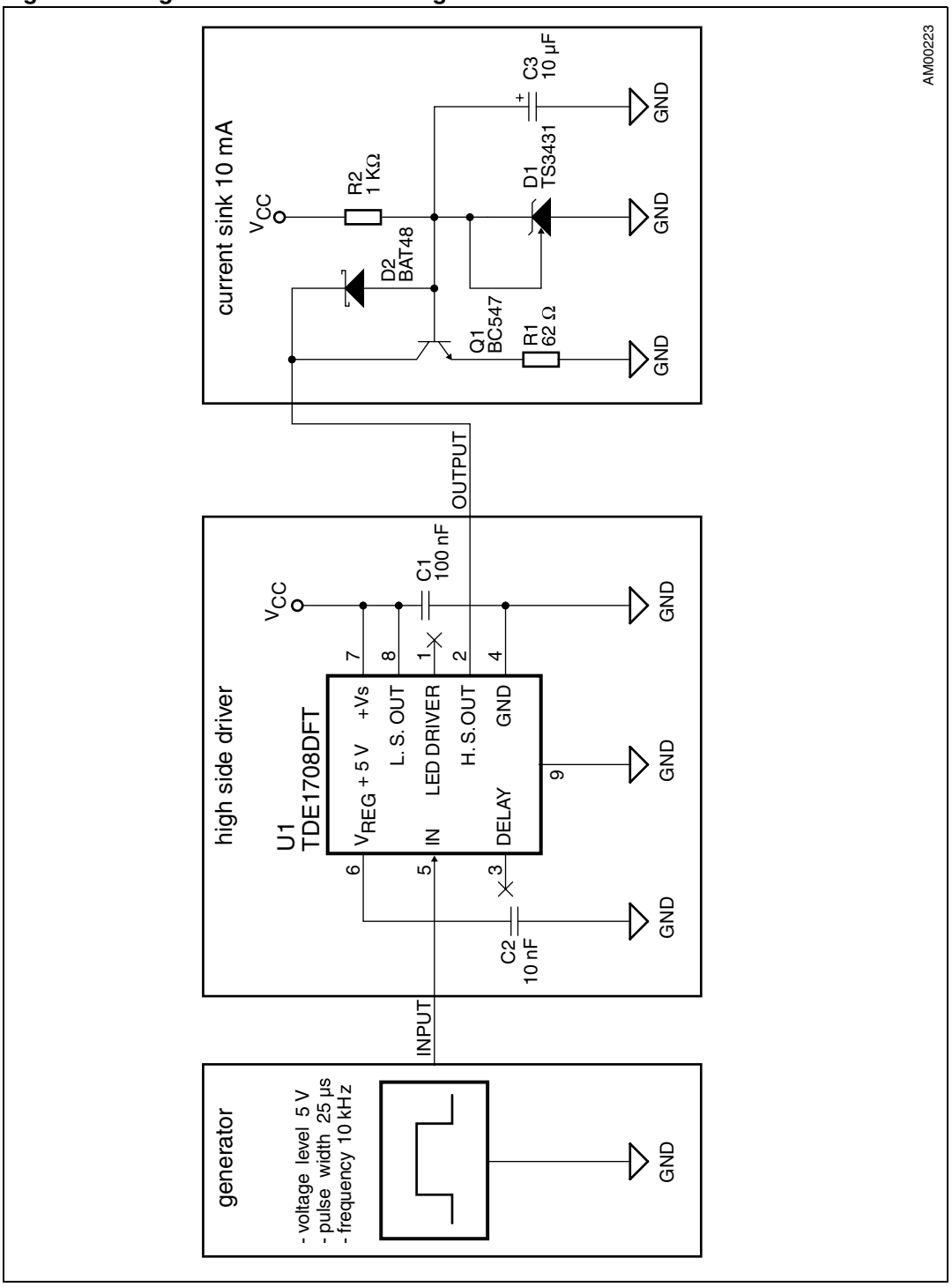


Figure 3. High-side switch configuration turn-on behavior(1)

Tek Stopped Single Seq 1 Acqs 22 Jan 08 02:30:13
Ch1 5.0V Ch2 5.0V
M 4.0µs 125MS/s 8.0ns/pt
A Ch1 2.3V
Zoom 1 Ch1 5.0V 200ns
Zoom 1 Ch2 5.0V 200ns
Zoom 1 Ch4 50.0mA 200ns

1. CH1: input voltage, CH2: output voltage, CH4: output current (x10).

Figure 4. High-side switch configuration turn-off behavior(1)

Tek Stopped Single Seq 1 Acqs 22 Jan 08 02:32:11
Ch1 5.0V Ch2 5.0V
M 4.0µs 125MS/s 8.0ns/pt
A Ch1 2.3V
Zoom 1 Ch1 5.0V 200ns
Zoom 1 Ch2 5.0V 200ns
Zoom 1 Ch4 50.0mA 200ns

1. CH1: input voltage, CH2: output voltage, CH4: output current (x10).

2.2 High-side configuration with a capacitive load

Figure 5. High-side switch test configuration schematic with a capacitive load

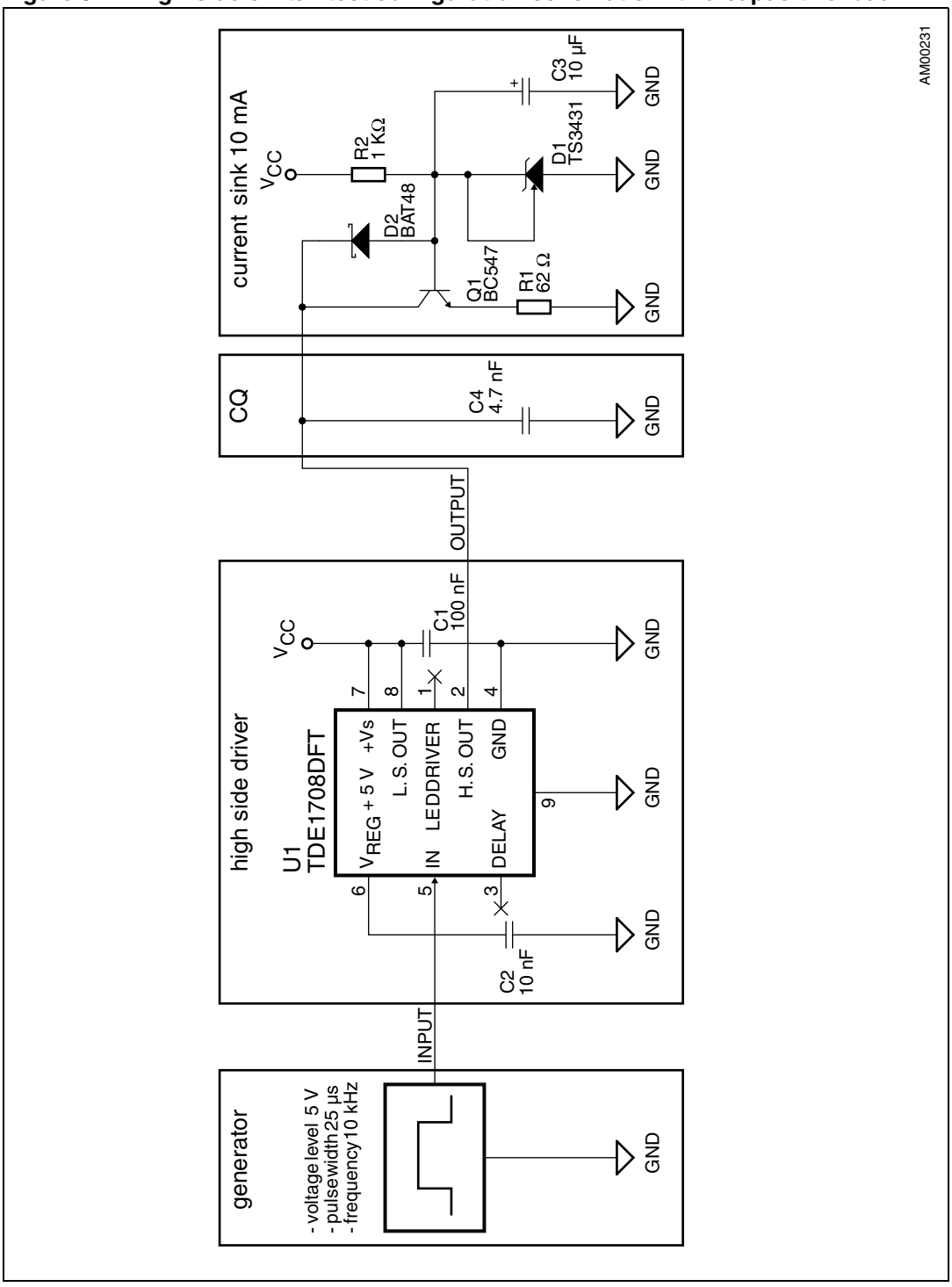
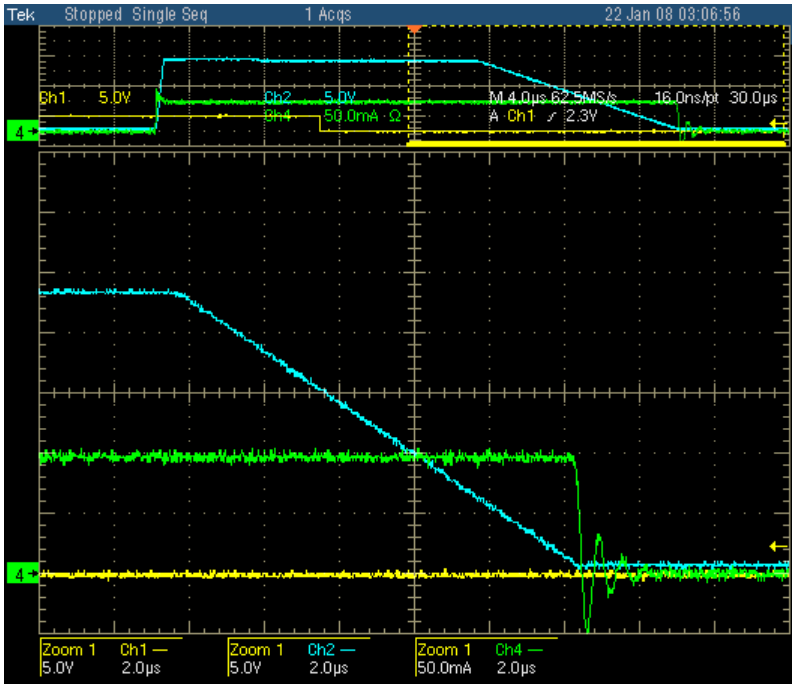


Figure 6. High-side switch configuration with a capacitive load turn-on behavior(1)

Tek Stopped Single Seq 1 Acqs 22 Jan 08 03:07:41
Ch1 5.0V Ch2 5.0V M 4.0µs 125MS/s 8.0ns/pt 30.0µs
Ch4 50.0mA Ω A Ch1 2.3V
Zoom 1 Ch1 5.0V 200ns
Zoom 1 Ch2 5.0V 200ns
Zoom 1 Ch4 50.0mA 200ns

1. CH1: input voltage, CH2: output voltage, CH4: output current (x10).

Figure 7. High-side switch configuration with a capacitive load turn-off behavior(1)


Tek Stopped Single Seq 1 Acqs 22 Jan 08 03:06:56
Ch1 5.0V Ch2 5.0V M 4.0µs 62.5MS/s 16.0ns/pt 30.0µs
Ch4 50.0mA Ω A Ch1 2.3V
Zoom 1 Ch1 5.0V 2.0µs
Zoom 1 Ch2 5.0V 2.0µs
Zoom 1 Ch4 50.0mA 2.0µs

1. CH1: input voltage, CH2: output voltage, CH4: output current (x10).

3 TDE1708DFT in low-side configuration

3.1 Low-side configuration

Figure 8. Low-side switch test configuration schematic

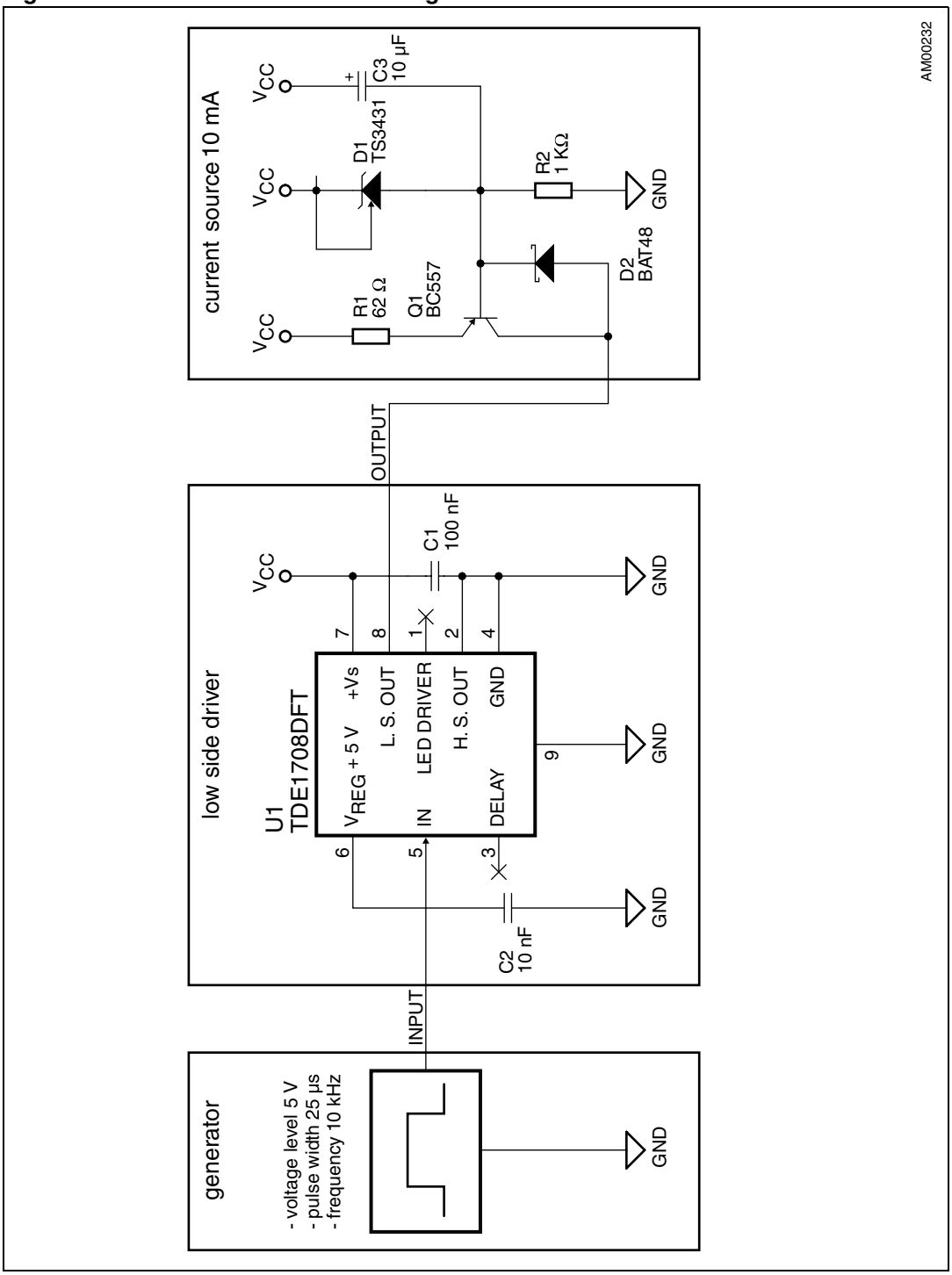
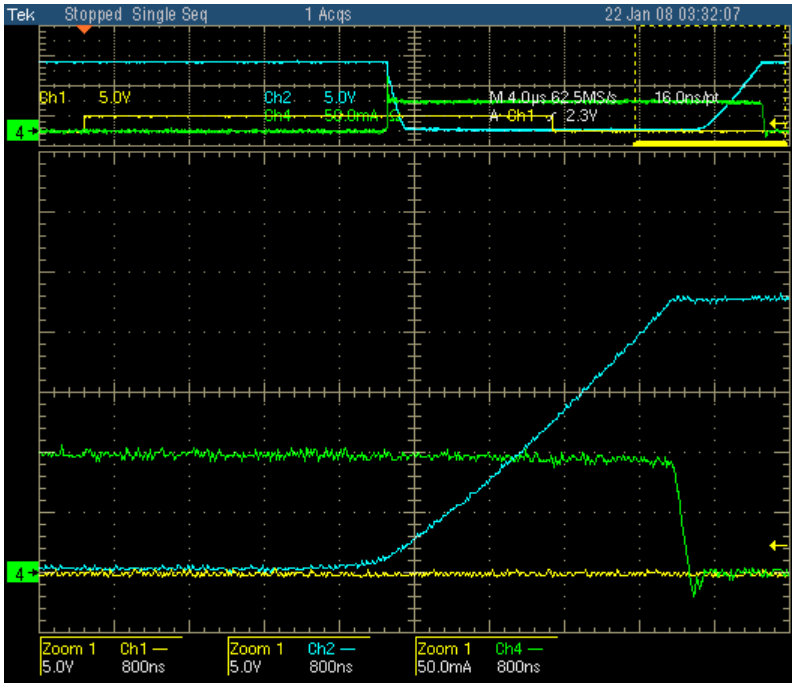


Figure 9. Low-side switch configuration turn-on behavior(1)

Tek Stopped Single Seq 1 Acqs 22 Jan 08 03:25:31
Ch1 5.0V
Ch2 5.0V
Ch4 50.0mA
M 4.0µs 125MS/s 8.0ns/pt
A Ch1 2.3V
Zoom 1 Ch1 — 5.0V 200ns
Zoom 1 Ch2 — 5.0V 200ns
Zoom 1 Ch4 — 50.0mA 200ns

1. CH1: input voltage, CH2: output voltage, CH4: output current (x10).

Figure 10. Low-side switch configuration turn-off behavior(1)


Tek Stopped Single Seq 1 Acqs 22 Jan 08 03:32:07
Ch1 5.0V
Ch2 5.0V
Ch4 50.0mA
M 4.0µs 62.5MS/s 16.0ns/pt
A Ch1 2.3V
Zoom 1 Ch1 — 5.0V 800ns
Zoom 1 Ch2 — 5.0V 800ns
Zoom 1 Ch4 — 50.0mA 800ns

1. CH1: input voltage, CH2: output voltage, CH4: output current (x10).

3.2 Low-side configuration with a capacitive load

Figure 11. Low-side switch test configuration schematic with a capacitive load

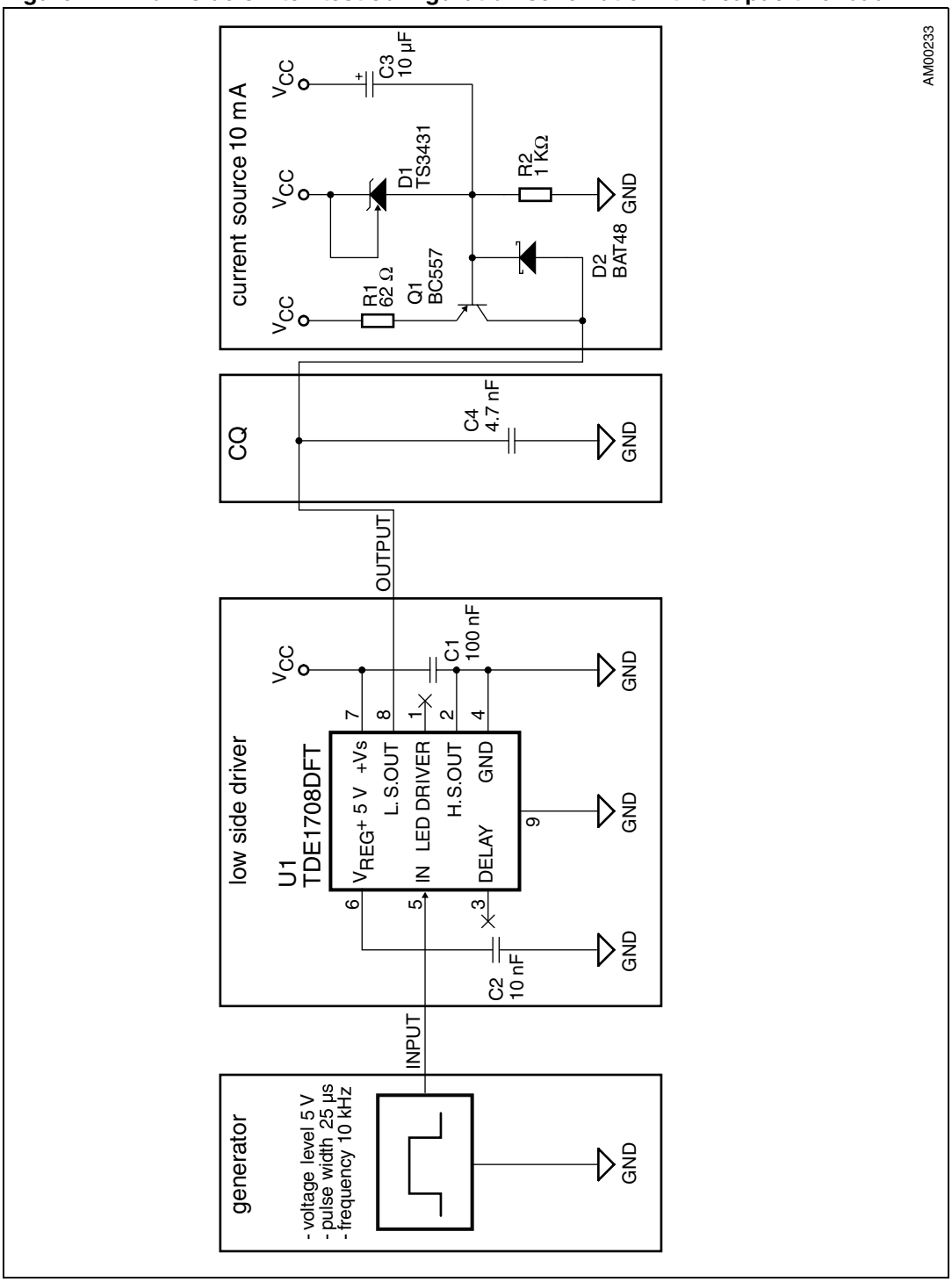
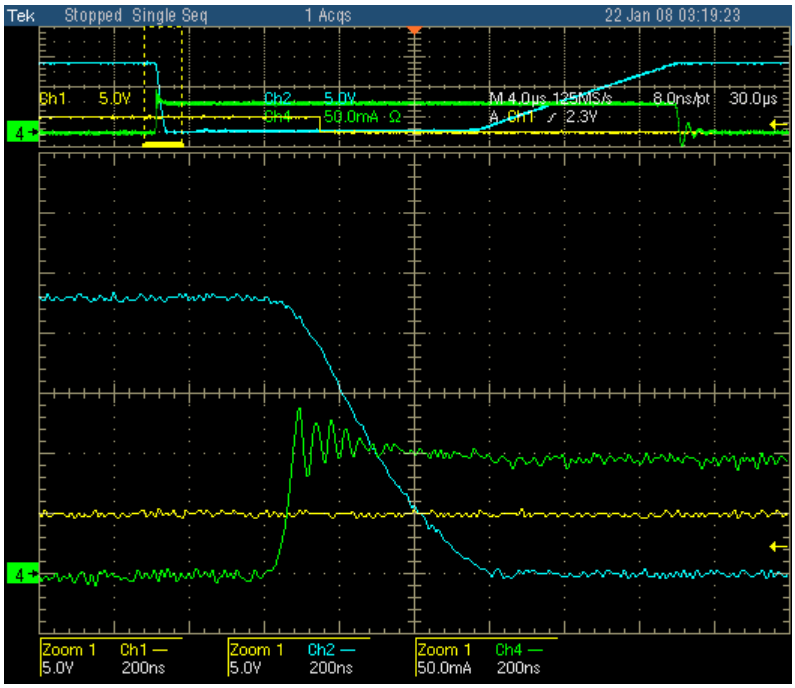
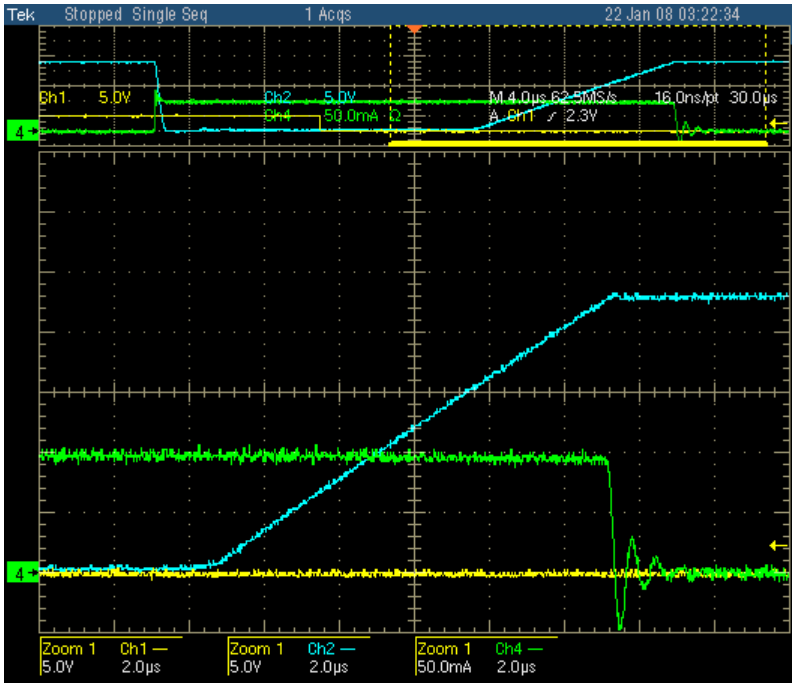


Figure 12. Low-side switch configuration with a capacitive load turn-on behavior(1)


Tek Stopped Single Seq 1 Acqs 22 Jan 08 03:19:23
Ch1 5.0V Ch2 5.0V M 4.0µs 125MS/s 8.0ns/pt 30.0µs
Ch4 50.0mA Ω A Ch1 2.3V
Zoom 1 Ch1 5.0V 200ns
Zoom 1 Ch2 5.0V 200ns
Zoom 1 Ch4 50.0mA 200ns

1. CH1: input voltage, CH2: output voltage, CH4: output current (x10).

Figure 13. Low-side switch configuration with capacitive load turn-off behavior(1)

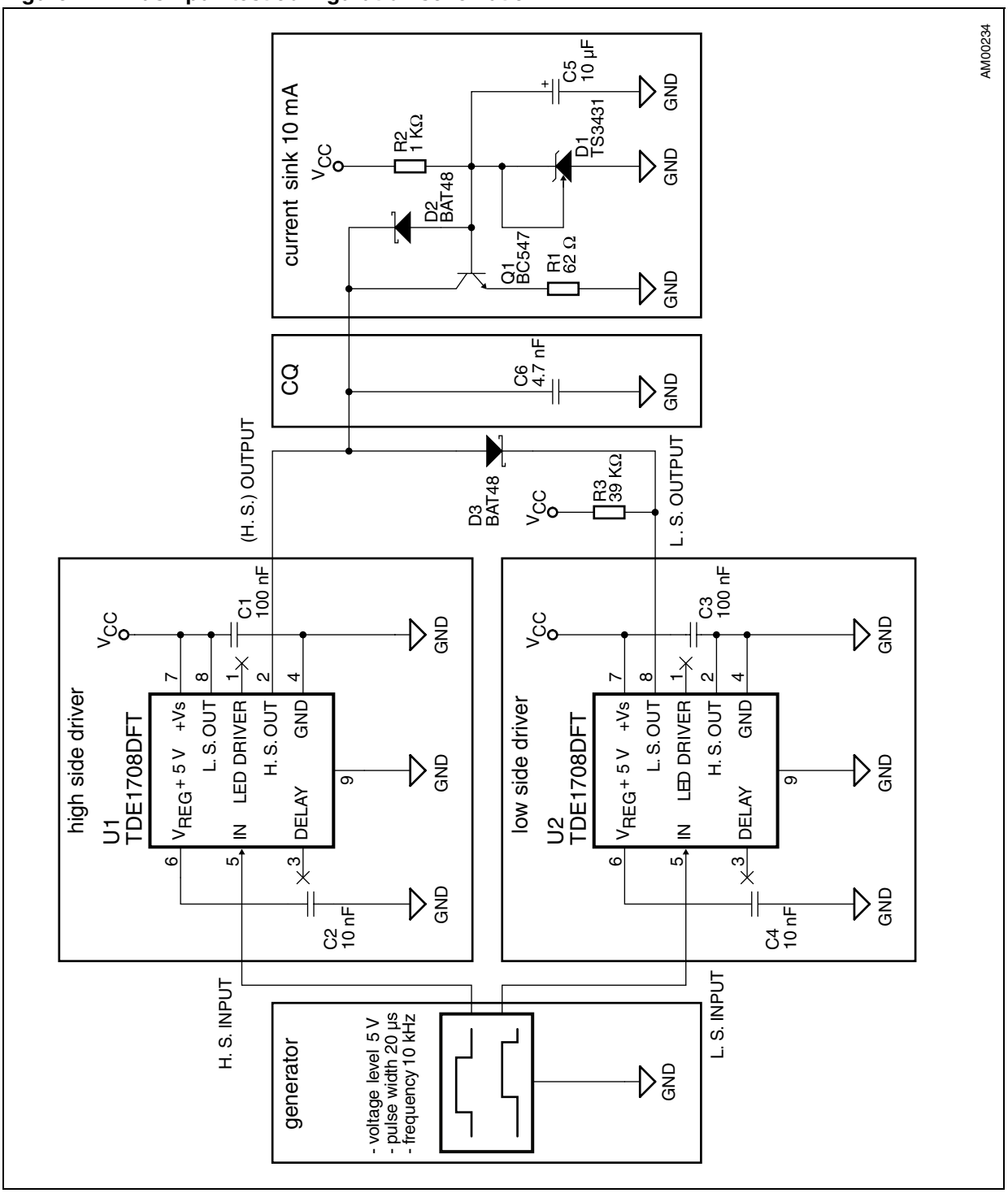

Tek Stopped Single Seq 1 Acqs 22 Jan 08 03:22:34
Ch1 5.0V Ch2 5.0V M 4.0µs 62.5MS/s 16.0ns/pt 30.0µs
Ch4 50.0mA Ω A Ch1 2.3V
Zoom 1 Ch1 5.0V 2.0µs
Zoom 1 Ch2 5.0V 2.0µs
Zoom 1 Ch4 50.0mA 2.0µs

1. CH1: input voltage, CH2: output voltage, CH4: output current (x10).

4 Push-pull configuration with TDE1708DFT

The following push-pull driver configuration was designed based on the previous single driver measurements. In this proposed schematic (see *Figure 14*) two additional components (R3, D3) must be added to speed up the turning off of the driver in the low-side configuration. The resistor R3 creates a weak pull-up while the diode D3 separates the low-side output from the high-side. The reason for this being that if the low-side driver is forced high in a short time after turning off then it stays turned on with all the subsequent effects.

Figure 14. Push-pull test configuration schematic

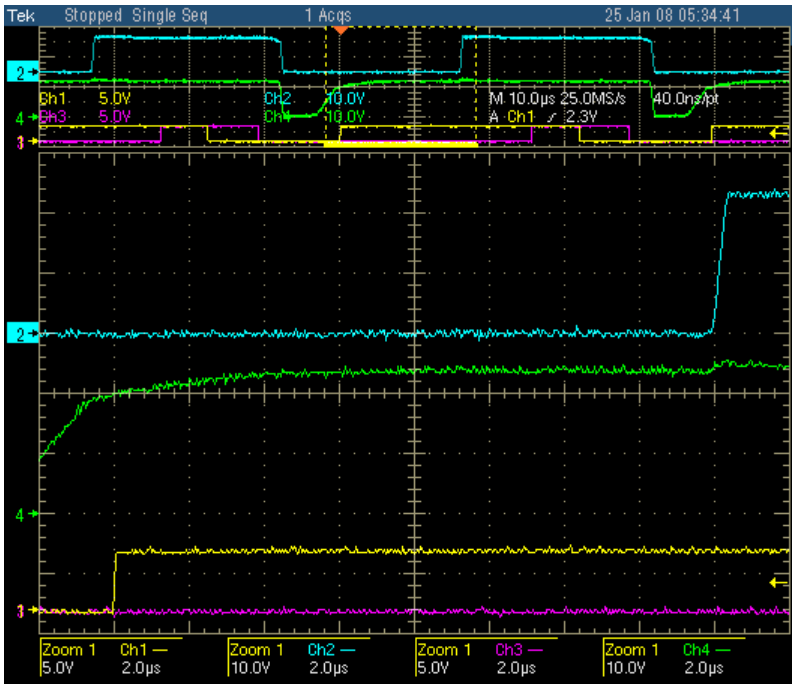


The low-side driver helps to reduce the falling time with the capacitive load, the rest of the circuit works exactly the same way as that described in *Section 2.1*. *Figure 17* shows a software timing example in accordance with *Table 2* and a dead time between the driver outputs of 1 µs.

Table 1. Push-pull configuration dynamic information (V_{CC} = 24 V; T_J = 25 °C; C_L = 4.7 nF)

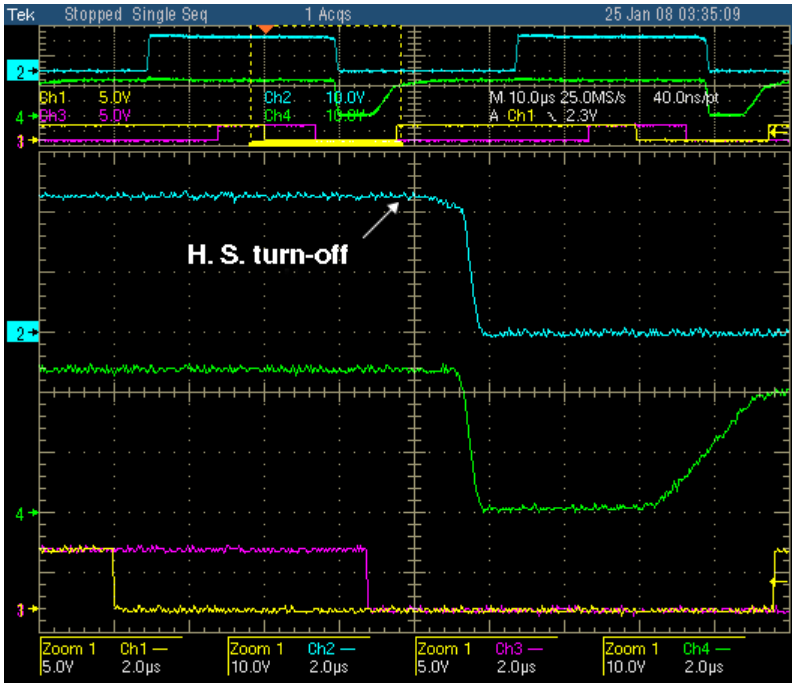
	Test conditions	Min	Typ	Max	Unit
Turn-on time	V_i = 0 to 5 V		800		ns
Turn-off time	V_i = 0 to 5 V		2		µs

Figure 15. Push-pull configuration with capacitive load rising edge(1)



1. CH1: input voltage, CH2: (H. S.) output voltage, CH3: input voltage, CH4: (L. S.) output voltage.

Figure 16. Push-pull configuration with capacitive load falling edge(1)



1. CH1: input voltage, CH2: (H. S.) output voltage, CH3: input voltage, CH4: (L. S.) output voltage.

Figure 17. Software timing example

```
@interrupt void AutoreloadTimerOverflowInterrupt (void){
  switch(ucState){
    case  1:  PADR |=  0x04;      // Output 0 -> 1; HS switch on (PA2 = 1)
              break;
    case  2:  break;              // Half of the output 1 period; do nothing
    case  3:  PADR |=  0x10;      // Output 1 -> 0; LS switch on (PA4 = 1)
              nop;    // 1us
              nop;
              nop;
              nop;
              nop;    // 1us      // Delay totally 5.75us. Due to the different
              nop;               // propagation times the low side switch turns
              nop;               // on "before" the high side one is turned off.
              nop;
              nop;    // 1us
              nop;
              nop;
              nop;
              nop;    // 1us
              nop;
              nop;
              nop;
              nop;    // 1us
              nop;
              nop;
              nop;
              nop;    // 500ns
              nop;
              nop;    // 250ns
              PADR &= ~0x04;      // HS switch off (PA2 = 0)
              break;
    case  4:  PADR &= ~0x10;      // Half of the output 0 period; LS switch off (PA4 = 0)
              ucState = 0;        // and again...
              break;
  }

  ucState++;                      // Increment state machine

  ATCSR;                          // Clear interrupt flag

  return;
}
```

5 Performance characteristics

5.1 Dynamic information

Table 2. Dynamic information (V_{CC} = 24 V; T_J = 25 °C; I_L = 10 mA)

	Test conditions	Min	Typ	Max	Unit
Propagation turn-on time	V_i = 0 to 5 V		16		µs
Propagation turn-off time	V_i = 0 to 5 V		8		µs

5.2 Temperature characteristics

Figure 18. Propagation turn-on time vs. temperature

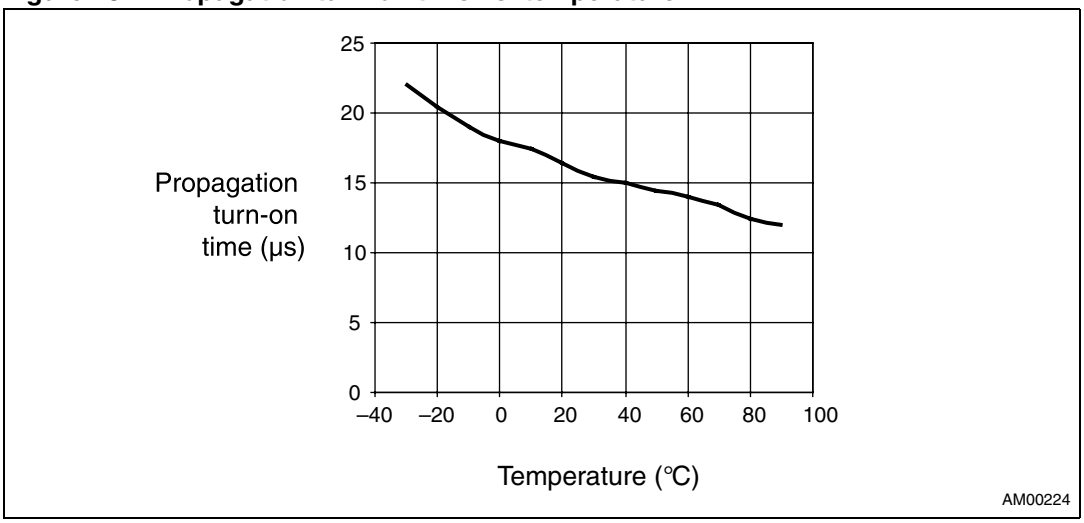
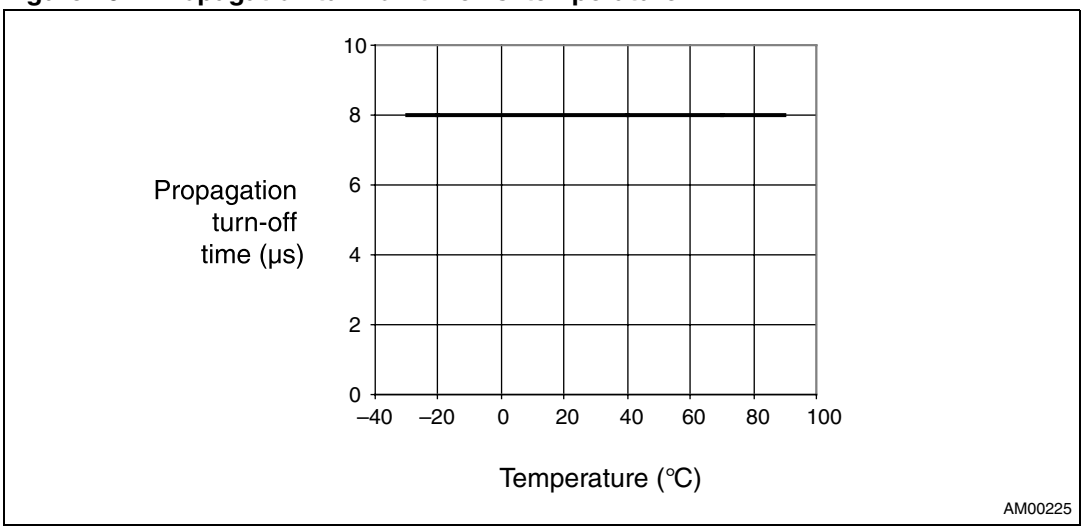


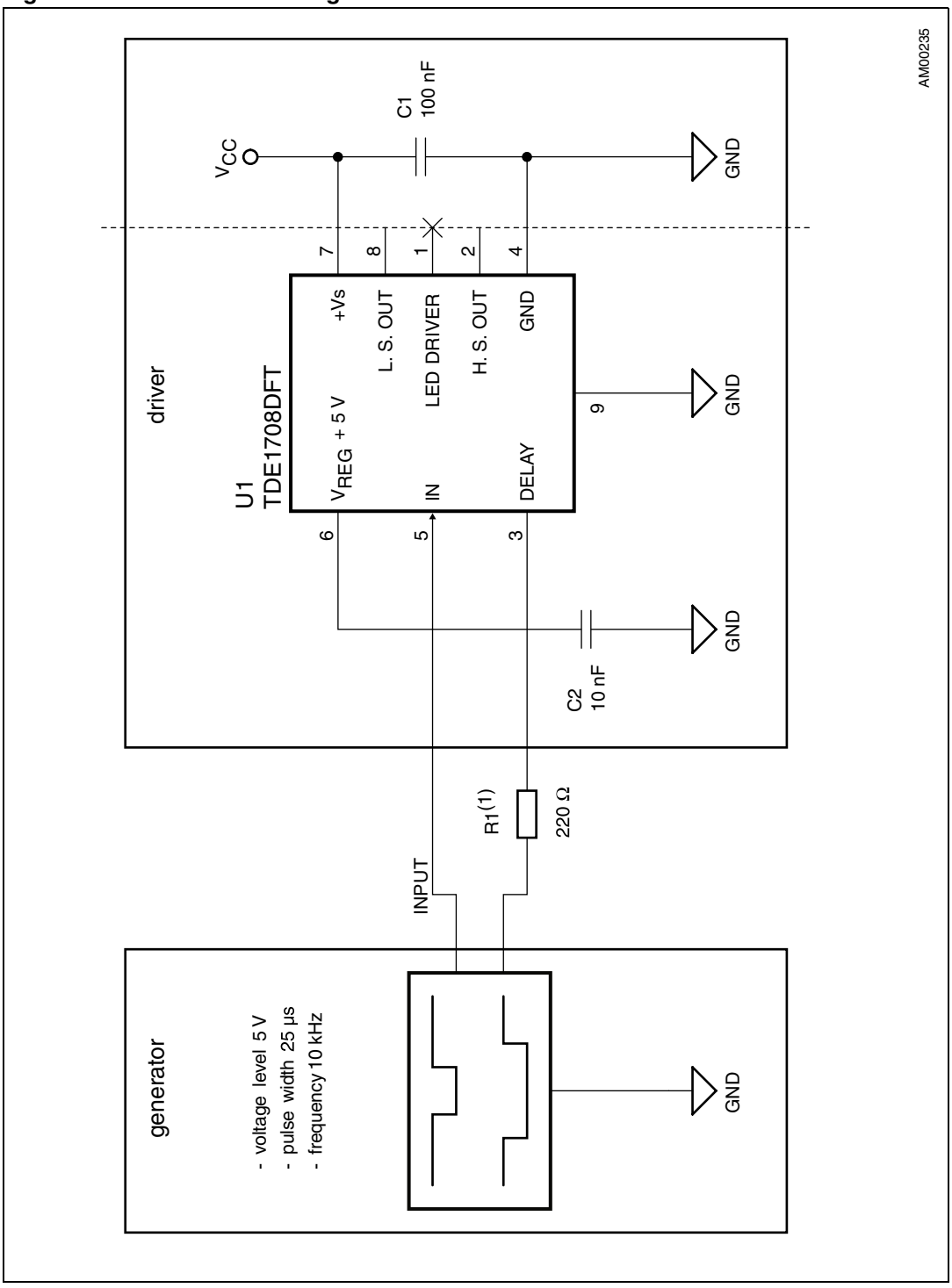
Figure 19. Propagation turn-off time vs. temperature



6 Alternative driving

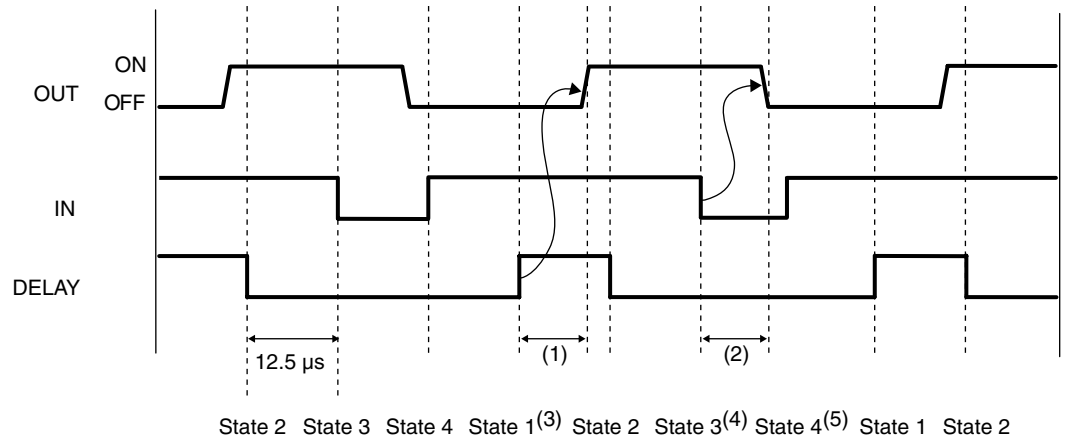
The larger temperature propagation turn-on time dependence of the TDE1708DFT, described in the previous section (*Section 5: Performance characteristics*), has led to the development of an alternative kind of driving which would not suffer from this problem. The presented driving configuration (see *Figure 20*) uses both the input signal “IN” together with the open collector pin “DELAY” (originally dedicated to delay adjustment). The IN signal controls only the turning off of the switch (the output is blocked by the DELAY pin during its high state), while the DELAY signal then controls the turning on of the switch (see *Figure 21*). This principle results in more positive temperature characteristics (*Section 6.1: Temperature characteristics*).

Figure 20. Alternative driving schematics



1. The resistor R1 prevents the circuit from the cross conduction between the push-pull output of the generator and the open collector DELAY pin.

Figure 21. Alternative driving timings



1. Delay propagation turn-on time (see *Figure 22* and *Figure 23*).
2. Propagation turn-off time (see *Figure 24* and *Figure 25*).
3. State 1: DELAY releases the output.
4. State 3: IN goes low and turns off the switch.
5. State 4: IN goes high, the output is blocked by the DELAY signal (the monostable circuit time meanwhile runs).

6.1 Temperature characteristics

Figure 22. Delay propagation turn-on time vs. temperature (H. S. configuration)

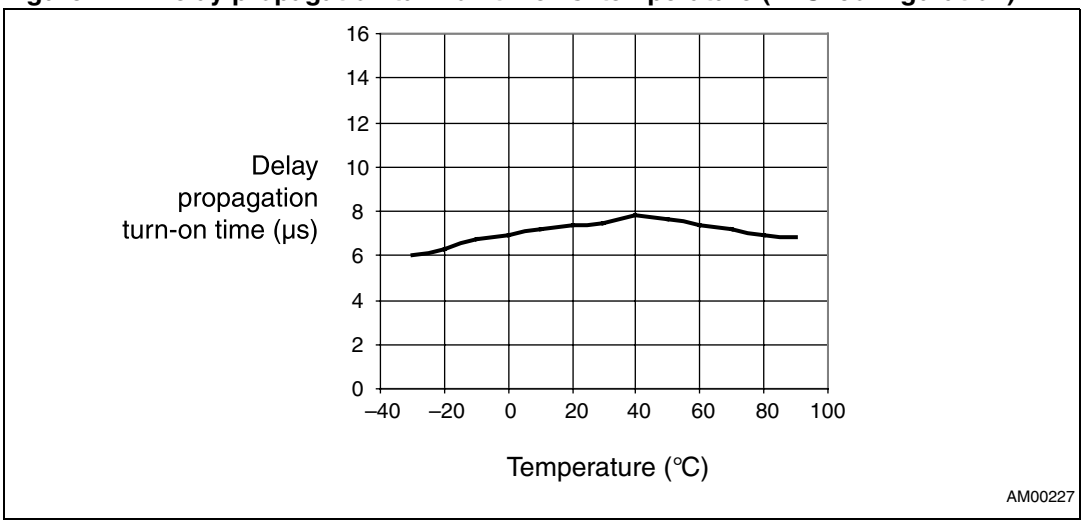


Figure 23. Delay propagation turn-on time vs. temperature (L. S. configuration)

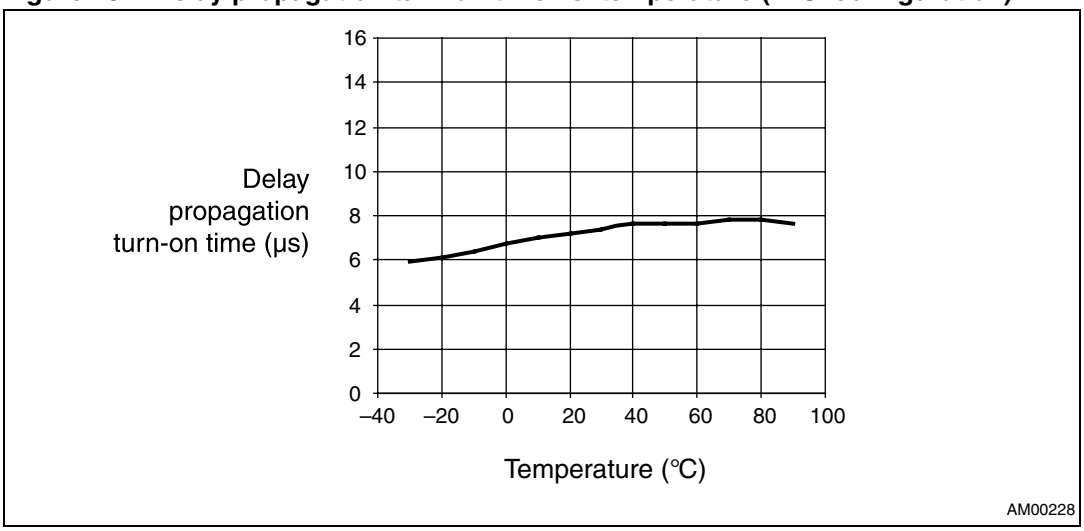


Figure 24. Propagation turn-off time vs. temperature (H. S. configuration)

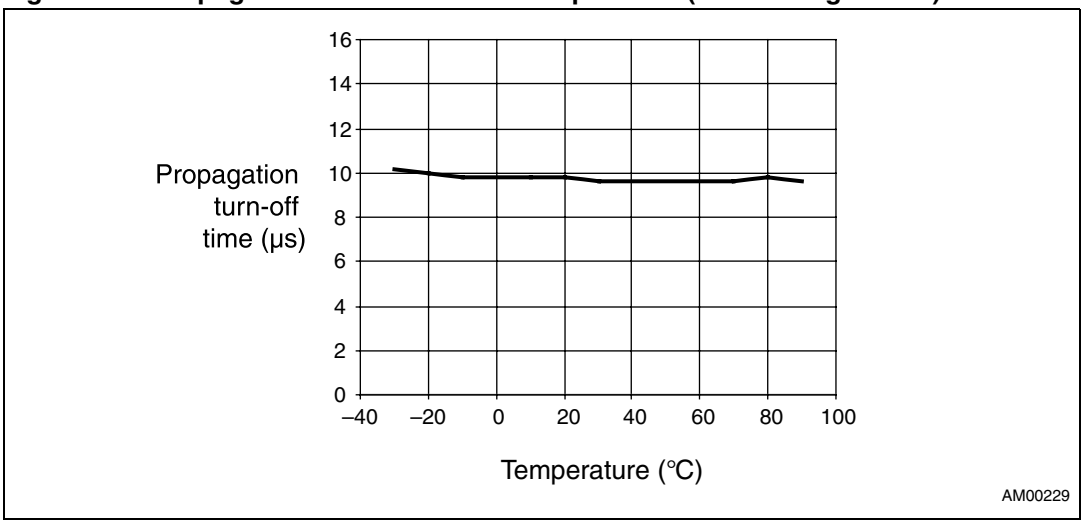
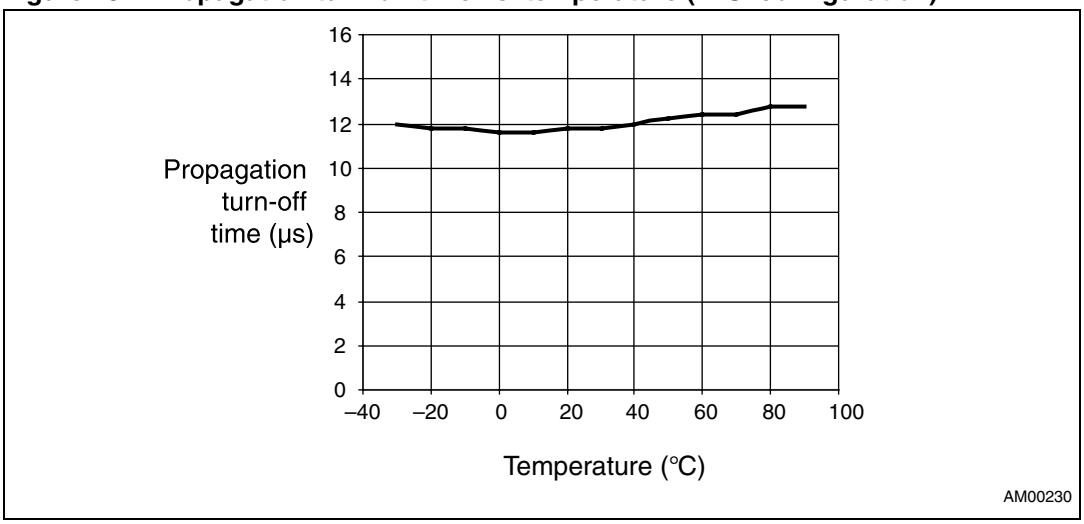


Figure 25. Propagation turn-off time vs. temperature (L. S. configuration)



7 Conclusion

With respect to the results obtained, the TDE1708DFT may be used in the operating mode COM1 (4.8 kBaud) in p-switching (high-side) 3-wire sensors and up to operating mode COM2 (38.4 kBaud) in push-pull 3-wire sensors.

Note: In the case of push-pull configuration a precise compensation of the propagation turn-on time temperature drift (Figure 18) is necessary to avoid cross conduction of the two switches. The alternative driving configuration (Section 6: Alternative driving) partially solves this issue for the price of employing two input pins for one switch.

8 References

1. TDE1708DFT datasheet.
2. AN495 application note.
3. IO-Link Communication Specification, Version 0.98, February 2007 - see: www.io-link.com/share/Downloads/IOL-Comm-Spec_10002_V10_090118.pdf.

9 Revision history

Table 3. Document revision history

Date	Revision	Changes
09-Feb-2011	1	Initial release.

Please Read Carefully:

Information in this document is provided solely in connection with ST products. STMicroelectronics NV and its subsidiaries (“ST”) reserve the right to make changes, corrections, modifications or improvements, to this document, and the products and services described herein at any time, without notice.

All ST products are sold pursuant to ST’s terms and conditions of sale.

Purchasers are solely responsible for the choice, selection and use of the ST products and services described herein, and ST assumes no liability whatsoever relating to the choice, selection or use of the ST products and services described herein.

No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted under this document. If any part of this document refers to any third party products or services it shall not be deemed a license grant by ST for the use of such third party products or services, or any intellectual property contained therein or considered as a warranty covering the use in any manner whatsoever of such third party products or services or any intellectual property contained therein.

UNLESS OTHERWISE SET FORTH IN ST’S TERMS AND CONDITIONS OF SALE ST DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY WITH RESPECT TO THE USE AND/OR SALE OF ST PRODUCTS INCLUDING WITHOUT LIMITATION IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION), OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

UNLESS EXPRESSLY APPROVED IN WRITING BY AN AUTHORIZED ST REPRESENTATIVE, ST PRODUCTS ARE NOT RECOMMENDED, AUTHORIZED OR WARRANTED FOR USE IN MILITARY, AIR CRAFT, SPACE, LIFE SAVING, OR LIFE SUSTAINING APPLICATIONS, NOR IN PRODUCTS OR SYSTEMS WHERE FAILURE OR MALFUNCTION MAY RESULT IN PERSONAL INJURY, DEATH, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE. ST PRODUCTS WHICH ARE NOT SPECIFIED AS "AUTOMOTIVE GRADE" MAY ONLY BE USED IN AUTOMOTIVE APPLICATIONS AT USER’S OWN RISK.

Resale of ST products with provisions different from the statements and/or technical features set forth in this document shall immediately void any warranty granted by ST for the ST product or service described herein and shall not create or extend in any manner whatsoever, any liability of ST.

ST and the ST logo are trademarks or registered trademarks of ST in various countries.

Information in this document supersedes and replaces all information previously supplied.

The ST logo is a registered trademark of STMicroelectronics. All other names are the property of their respective owners.

© 2011 STMicroelectronics - All rights reserved

STMicroelectronics group of companies

Australia - Belgium - Brazil - Canada - China - Czech Republic - Finland - France - Germany - Hong Kong - India - Israel - Italy - Japan - Malaysia - Malta - Morocco - Philippines - Singapore - Spain - Sweden - Switzerland - United Kingdom - United States of America

www.st.com